THE WATER-SUPPLY OF CITIES.

A COPIOUS and constant supply of pure water is a source of comfort, luxury, safety and health, and has become a necessity of modern civilization. The most refined and cultivated nations have always been large consumers of water. With the Orientals cleanliness is akin to godliness. Mahomet directed a disciple to commemorate his mother by digging a well, and Jacob's well is one of the oldest relics of antiquity. The baths of Diocletian and the aqueducts of Rome, with the reservoirs of Jerusalem and Damascus, are colossal triumphs of engineering. Yet, despite the magnitude of the water-works of the Orientals, Greeks and Romans, and their lavish supply for public uses and in the houses of the rich, the ancients seem to have had no conception of the modern use of water as a sanitary necessity to the community at large. Furthermore, many modern applications of water, as for fire service, sprinkling streets and lawns, flushing sewers, and to supply manufactories, laundries, hotels, elevators, steam-engines and railroads, were wholly unknown to them. The great cities of the past were supplied from huge rock-hewn cisterns for receiving and storing rain, or by aqueducts which often extended for miles, spanning valleys and rivers, and conveying a daily supply for each inhabitant often three or four times greater than we can now provide. With the introduction of Christianity, and owing largely to the immoral practices connected with public bathing, the latter habit was discouraged by religious teachers and fell into disuse, so that personal cleanliness became exceptional, and the filthy habits of the masses undoubtedly promoted the spread of the plague and other great mediæval epidemics.

Dublin was one of the first modern cities to introduce a public water-supply. This occurred in the thirteenth century, when in most cities of the European continent the supply was provided by street carriers. A curious regulation provided that the pipes

connecting with individual dwellings should not exceed the size of a goose-quill, which indicates the value put upon the water. London did not have a public supply until some four hundred years later, and then through the munificence and public spirit of some lord mayor or sheriff anxious to distinguish his term of office by conferring so great a boon upon his constituents. In 1582 a Dutch engineer erected a water-wheel at London Bridge, the first pumping machinery used in England. The earliest efforts to supply Paris with water were under the patronage of religious bodies, the oldest aqueduct having belonged to the Abbey of St. Laurent. Paris depended upon the Seine and small aqueducts until within a few years.

An English chronicler quaintly describes the "contempt, scorn, derision, yea, and desperate despight" which the early projectors of water-works in London met with from "accursed and malevolent" persons. Afterward, when numerous water companies had been chartered as purely commercial enterprises, the rivalry bred by competition was carried to the verge of ruin. The different companies finally consolidated, and the interests of consumers were sacrificed to monopoly. The supply was intermittent, flowing only a few hours each day or even week; storage-tanks were necessary in every house; very large mains were needed to convey the supply within a brief period, and duplicate mains were required for fire purposes; the domestic cisterns were exposed to contamination, and their contents became stale and warm; while, worst of all, the original source of supply was polluted with sewage and factory refuse. Parliament finally interfered, and decided that the principle of competition was not applicable to water companies. The cholera epidemic of 1848–49 caused such a panic that the companies were forced to take their supply from more distant points. Numerous royal commissions have since pointed out the unsatisfactory character of the London water. In 1871 a bill for the compulsory purchase of the water companies by the Government was introduced, but failed to pass. At present the evils of the system are becoming intolerable. Large masses of population are dependent upon shallow wells in sewage-soaked soil. Dr. Frankland, the eminent chemist, reports that the largest volume of water conveyed to the city is seriously polluted with sewage, while the water examiner for London states that the storage-cisterns are fertile sources of impurity. At a public meeting held at Exeter Hall, about two

years since, Cardinal Manning, the Bishop of London, and other speakers insisted that the authorities must take some action in the matter to protect both morals and health.

The amount of water required for a community depends upon the character of the population. Where bathing is habitual, the supply must be copious. So, too, in a manufacturing city, it will not do to restrict consumption; a single paper-mill, brewery, or gelatine works may consume more than a thousand individuals. An abundant supply is also needed for boilers, elevators, public fountains, to extinguish fires, and to wash the streets, while the whole amount is finally used to flush the sewers —an important sanitary service. The amount of water usually required to meet all domestic demands is estimated from ten to forty gallons per head. The temptation to waste, however, is so great, that two and three times this amount per day is often drawn. In London, exact measurements show that workingmen's families consume four and a half gallons per head if taken from street-hydrants, but from five to fifteen gallons if from separate taps in each house. In large houses the consumption often reaches seventy gallons per head. Thirty gallons per head is considered a liberal allowance for ordinary sewered towns with average manufacturing interests. The domestic consumption is largest on wash-days. In hot weather it increases twenty per cent.; but in time of frost the excess, chiefly from waste, is from thirty to forty per cent. New York consumes ninety-five gallons daily per head of population; Liverpool, sixty; London, thirty; Paris, thirty-eight; Dublin, sixty; Glasgow, fifty-two; Manchester and Birmingham, each twenty.

In calculating the amount of water to be provided, allowance must be made for future as well as present needs. Provision should also be made, in case of emergency, for an amount greatly in excess of the ordinary consumption. At the great Boston fire of 1872, when the daily consumption averaged twelve and a half million gallons, the fire department used eighteen and a half million gallons, mainly during the first eighteen hours of the fire. Where the daily consumption exceeds five million gallons, duplicate pumping apparatus are considered necessary to meet the chance of a break-down. If the consumption is less, a reservoir capable of storing a week's supply will suffice. Next to the question of quantity comes that of quality. A potable water should be colorless and clear. It

should be soft and have little mineral matter in solution, while it should be absolutely free from organic contamination. Most persons will reject pure water which happens to be turbid, in favor of sparkling, colorless water, drawn from a polluted spring, provided it has no peculiar taste or odor; yet, in localities where clear waters are hard and unfit to drink, turbidity becomes a recommendation.

Pure water, to judge from the statements of chemists, physicians, and sanitarians, is a rarity in most localities. In rural districts, as a glance from any railroad car window will prove, the uniform nearness of wells, cisterns, stables, pig-pens, cess-pools, in the usually porous soil, leaves no doubt of the contamination of the water-supply. An English analytical chemist of large experience says that scarcely a single sample of water brought to him from farms, country-seats, and private houses in the country, had proved to be pure. The Sixth Report of the Rivers Pollution Commission states that twelve millions of people depend upon shallow wells "almost always horribly polluted." Mr. James C. Bayles's clever parody upon "The Old Oaken Bucket" should be in every collection of household poetry; it shows that in too many cases the ordinary domestic supply, instead of being the sparkling and refreshing water of the poet's fancy, is really more akin to Macbeth's witches' hell-broth. It is a curious circumstance that, if a child or servant falls ill in the country, the water rarely comes under suspicion; but, if cattle are affected and die, it is at once examined. People will freely use water which has to be filtered of visible and even living impurities. Bad drinking-water is an ever-present peril to rural residents, and an ever-recurring one to their occasional visitors. Hence, diseases due to polluted water prevail as largely in the country as in the city, and are often imported from the former to the latter.

Nevertheless, for many communities, wells, if properly located and guarded against contamination, may prove the best available source. When houses are more numerous than two to the acre, dependence must be placed on driven wells, which may supply a whole community, if judiciously placed. The permanent yield of any well depends upon the local geological formation, and such an expensive work as sinking one should never be undertaken without competent professional advice. A slight intelligent examination will often determine whether the proposed

source of supply is inexhaustible or temporary and intermittent. Driven wells of iron tubing are well adapted for localities where the soil is free from stone. They have been much used in military expeditions from the rapidity with which they can be sunk, but they need to be protected from contamination.

Artesian wells are often used to supply small towns or establishments consuming large quantities of water, as breweries, hotels, laundries, mineral water manufactories, etc. Their yield is sometimes large, and, as the temperature of the supply is low, a great saving may be made in the outlay for ice. In London, where these wells penetrate the chalk-beds, a yield of from one and a half to two and a half million gallons per day has been obtained. Wells of like capacity exist in Liverpool, Paris, and other cities. There are eighteen hundred in New-York city, with an estimated daily product of twenty million gallons, which saves one thousand dollars per day to their owners. In Boston nine-tenths of the large factories are supplied from similar sources. Among the places supplied from wells may be named Memphis, Covington, Ky., Kansas City, Mo., Dayton, O., Long Island City, Garden City, and Prospect Park in Brooklyn.

Artesian wells are costly to bore, and often fail to yield good water, while their supply is not always permanent. The famous Grenelle well in Paris, one of the deepest on record, at first yielded eight hundred thousand gallons daily, and afterward declined to two hundred thousand. Again, the water from deep wells is generally strongly charged with lime or more objectionable minerals, which renders it unfit for domestic use. It is too hard for laundry purposes without boiling, and it causes incrustation in boilers, and is often unwholesome. A late examination by the New York Board of Health, of fifty samples of water from such wells, showed a large proportion of mineral and organic matter.

The effect of water-pollution upon health has been repeatedly published. Goitre is caused by drinking water impregnated with animal matter, and disappears when pure water is substituted. In Great Britain one hundred and sixty-four epidemics of enteric fever were traced in four years to impure air or water—usually both, and six thousand eight hundred and seventy-nine deaths occurred in a single year from these causes. In the historic outbreak at Over Darwen two thousand cases of sickness and a hundred deaths resulted from a polluted water-supply. A simple test for pure water, such as might be used by

ordinary householders, is very desirable; but none exists, and it requires much skill to prove that water is absolutely pure. Chemical tests are uncertain. The taste is not to be depended upon, as the most palatable water is often the most impure. In India, examination of some of the wells used by the pilgrims showed that the so-called holy water consisted of almost pure sewage. The frequent outbreaks of cholera among these visitors is therefore explained. So difficult has it become to obtain pure water on the Continent of Europe, that the eminent English physician, Sir Henry Thompson, in a letter to the London "Times," warns travelers never to touch a drop in any place, or under any circumstances, unless it can be boiled before using.

Fresh-water ponds and lakes are perhaps the best source of public supply. They are less apt to become turbid, matter in suspension being deposited as sediment, while organic matter in solution is purified by the oxidation of the air. They are also less likely to be selected as sites for manufactories or towns, and hence are less exposed to pollution by the waste products of industry or sewage. Shallow ponds are not desirable, or those whose margins are liable to be exposed in seasons of drought. Ponds are so numerous as to afford an almost unlimited supply. In Massachusetts alone their area is estimated at ninety-two thousand nine hundred and thirty-eight acres.

The banks of rivers from time immemorial have been the sites of towns, whose inhabitants have naturally used the streams as sewers, while their water privileges have invited manufactures, whose waste products have been added to the first source of contamination. Some of these waste substances are harmless to health, but many are unwholesome. A great deal has been done in the direction of rendering them innocuous, but it is almost impossible to do this completely. In England the consequent pollution of water-courses has excited public alarm, and led to stringent legislation. Owing to the greater size of American rivers, this evil has not become so formidable here; yet, in the case of the Merrimac, the Passaic, and the Ohio, not to name others, it is attracting serious attention. There is a prevailing impression that large flowing streams are self-purifying, and chemical tests have apparently confirmed this belief, from their failure to show serious contamination in streams at a distance of some miles below a point where sewage or other products were discharged into them. This, however, is a mistaken view.

Even though by oxidation, deposition, and dilution, the potency of many impurities may seem to be greatly lessened, yet this may be only because of the inefficiency of chemical tests. In view of the extraordinary vitality of disease-germs of all kinds, and the effect of impure water in promoting typhoid and other zymotic diseases, the conclusion of the best sanitary authorities seems rational, that it is not safe to use, for domestic purposes, water known to be seriously polluted.

A further objection to rivers is that they become turbid during freshets, and receive impurities from various sources, as dissolved vegetable matter, eroded and decomposed rock, the drainage from marshes or peat-beds, etc., according to the geological formation of the locality. Their high temperature in summer is another objection, especially where ice is not abundant or cheap. Great stress is laid upon this consideration in Europe, especially on the Continent, and a uniform temperature is considered very desirable. Furthermore, rivers usually follow the lowest level, and hence there is difficulty in raising water high enough to supply dwellings without power. Where there is a fall, pressure may be produced by water-wheels, in connection with a surface reservoir, as in the Cochituate water-works, or steam pumps may be used, though they are costly in operation. A weir or dam is sometimes built across a river-bed, to allow impurities to settle before the water enters the mains.

As a security against fire, a public water-supply is a wise investment. The losses by fire in the United States, in 1882, amounted to seventy millions of dollars. A hotel, theater, church, or other large building is burned every day. The great conflagrations in New York, Chicago, Portland, and Boston marked epochs in our history. Every little while a whole village is swept away for lack of some provision against fire. The consequent loss falls on the whole community through the fire insurance companies, and it is to the interest of all to reduce it to a minimum. Private apparatus usually fails in the time of need, and a public supply is the only safe reliance. The fire protection side of the water-supply question has a vital interest to the inhabitants of large cities, in view of the growing popularity of huge flats and office-buildings filled with combustible material and only fire-proof in name, whose lofty elevator shafts and stairways are but flues to spread flames instantaneously from cellar to roof, and whose height, while inviting draughts

of wind from every direction, renders of no avail the best pumping apparatus.

The experience of New York in securing an abundant public water-supply, is typical of that of other cities. Up to the beginning of the present century, wells and cisterns were depended on, and their product was vended through the streets. The Manhattan Company was then chartered, and built a reservoir in Chambers street, from which wooden pipes conveyed the water. This arrangement was displaced by the Croton aqueduct in 1842. The population was then three hundred thousand, and the capacity of the aqueduct sixty million gallons daily. It was expected to meet the city's needs up to the year 1900, but its designers did not anticipate the rapid growth of population, or the increased consumption due to improved plumbing and the development of industrial enterprise. Instead of the single sink and hydrant, which then sufficed most householders, hot and cold baths, basins, and water-closets are now found everywhere. Many tenement-houses are better provided with water than the best dwellings of forty years ago, while the most lavish supply is needed to meet the luxurious habits of our wealthy citizens. In less than twenty-five years the city's consumption doubled, and an additional reservoir had to be built. For nearly ten years it has been necessary to force the aqueduct, at great hazard, to carry thirty-five million gallons in excess of its intended capacity. At present it is always full, and in great danger, under the existing pressure, of leakage and mishap. Since the erection of the high service works at High Bridge and Ninety-seventh street, nothing has been done to obtain an added supply, and the expenditure has been solely for maintenance. The most startling fact in this history is that the bulk of the ninety-five million gallons brought to the city is not used, but wasted. Furthermore, for long periods the supply in the Croton Valley has been so abundant that five hundred million gallons per day has been running to waste over the dam. It has, therefore, been possible to use only one-sixth of the supply which would be available if there were sufficient storage and aqueduct capacity to retain and convey it. Niagara itself would not contribute a drop more water than is now distributed by the present aqueduct. It is almost impossible, during a large part of each day, to draw water on the upper floors of most houses not provided with tanks, and hence there is no supply to flush

plumbing fixtures and prevent foul odors. These annoyances and evils must continue with the inevitable decrease in pressure from the city's growth, until a new aqueduct can be built. The remedies for the scarcity of water are, first, to build a new aqueduct; and second, to check the present waste by methods employed in other cities where the same evil is complained of, and which have already been tested here.

The chief sources of water-waste are well stated by the Water Register of Boston to be the use of so-called self-acting closets; urinals which are constructed for a continual run of water; the use of hand-hose for the purpose of irrigation; bad plumbing materials and bad plumbing-work; and the steady run of water which is permitted in winter time to prevent freezing. Close competition among manufacturers of plumbing material has caused great deterioration in its quality. The market is flooded with inferior water-fixtures, which from their cheapness are largely used, while their inefficiency and wastefulness is increased by bad workmanship. Being hidden from view, an imperfect joint, a leaky valve or faucet, may escape notice perhaps for months, and prove a source of constant waste. In Boston a single defective Hopper closet, such as is everywhere used by domestics, was found to have wasted four hundred and seventy-five thousand five hundred and ninety-five gallons, and by changing thirteen such fixtures for others a saving of three and one-quarter million gallons was made in a single year. There are sixteen thousand one hundred and thirty-seven such appliances in use in that city, which at the same ratio would waste four and one-half million gallons every twenty-four hours. A tax of twenty dollars is to be levied on such water-closets in New York, and seems reasonable, as they are usually allowed to run unceasingly.

In Chicago the consumption averages a hogshead and a half for each man, woman and child, which Mr. Chesborough justly pronounces "evidence of enormous waste." Chief Engineer McFadden, of Philadelphia, says the useless waste of water in all American cities demands a supply double that of European cities, to maintain which requires great outlays, or the introduction of meters to control this needless, if not criminal waste.

Much diversity of opinion exists relative to the use of water-meters. The general conclusion seems to be that, while they are desirable in the case of breweries, hotels, factories, stables, and other places where a great quantity of water is re-

quired, they are not to be recommended for private houses, from the chance that imposing a price upon the consumption may lessen the sanitary use of water. No restriction should be made that would lead people to avoid bathing, or freely flushing plumbing fixtures. Anything which discourages a liberal use of water is an obstacle to social progress.

In Liverpool, district meters have aided in the stoppage of leaks, and have reduced the daily consumption one-half, and in Fall River and Providence they have worked well. The Boston Water Board, in their just issued report, favors their use, but admits their costliness and difficulty of general adoption. The prime object of the meter, as its name indicates, is not to obtain revenue, but to discover and prevent waste. It is claimed that nothing but such an adjunct will lead householders to correct defects in their water-fixtures. The saving thus effected would, in a few months, pay for the cost of the meter. The problem is to insure the use of the whole available supply, not to limit it. The recovery of one-half of the water now wasted means a constant supply for fixtures on the upper floors of hundreds of houses which now are left without supply most of the day, and would obviate the necessity of storage-tanks in many places.

The New York Fire Department consumed only thirty-three million gallons last year, or a little more than one-third of a single day's supply. The elevated railways consume about one and one-third million gallons daily, and the hotels a little larger amount. Many of the latter have private wells. Steam-engines use a million gallons per day. In brief, all the larger consumers united do not consume four per cent. of the total supply, and the water-waste is chiefly among householders. Charitable institutions are said to be prodigal of water, in one hospital two hundred gallons per head being daily consumed. Fifteen thousand meters are used in New York, the charge being one cent per hundred gallons. The conclusion of the whole matter, so far as New York city is concerned, may be thus stated: the population is still growing, and with it the demand for water. No dependence can be placed upon wells for domestic needs, and the public supply must therefore be increased. Those who now have an abundance of water should not be restricted; those who are denied this privilege should have their fair quota. A new aqueduct will take years to build; meantime the present supply must be employed to the best advantage, all waste must be checked, and the public urged and required

to use the water reasonably. Householders must be taught that there is no advantage to health in letting water run continuously, and that a small stream from a faucet or valve will not flush a soil-pipe or sewer; also, that the way to prevent supply-pipes from freezing is to protect them from frost. It is noteworthy that the bulk of the waste is found in a small number of houses,—about four per cent. of the whole,—and therefore it is to the interest of the majority to stop this extravagance of a few. A plan for a new aqueduct has been prepared, which has the approval of engineers of world-wide reputation, ability, and integrity; and it is to be hoped, and seems probable, that it will be soon carried out. Longer delay is dangerous.

English experience has shown the error of allowing a watershed to be appropriated by the first comer who may come along, and that the interests of small as well as large communities must be considered. A national movement, under the auspices of the Prince of Wales, has there been set on foot to district the whole of England and Wales, so as to distribute the water-supply equitably among the whole population. Small communities often have as much trouble to obtain pure water as large cities. Hence, in constructing reservoirs and aqueducts to provide for the latter, provision should also be made for similar places along the line of conveyance.

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